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Distribution of organic carbon in particle size fractions of a red soil under long-term fertilization

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Summary

Soil samples were collected from two depths *i.e.*, 0-15 and 15-30 from the long term experiment field at Zonal Agricultural Research Station, GKVK Bengaluru after harvest of maize in the year 2008 to study the soil organic carbon (SOC) distribution in particle size fractions. The soil was sandy loam of texture with acidic pH and low organic carbon status. The results of the study revealed that the soil pH was decreased due to the imbalanced fertilizer treatments and was maintained near initial level due to treatments involving both balanced fertilizers and FYM addition. The use of organics alone or organics along with fertilizers resulted in build up of SOC compared to use of only inorganic fertilizers. Soil organic carbon estimation in each size fraction indicated that the clay fraction had the highest OC concentration followed by silt and sand in the both depths of the soil. Soil organic carbon in sand declined rapidly upon cultivation, mostly due to oxidation and disintegration of unstable aggregates to enter silt-size or clay-size fraction because of intensive cultivation of the soil for 25 years. The study revealed that C was very slowly sequestered in the clay and silt fractions of the soil.

Key words : Soil organic carbon, Particle size fractions, Carbon enrichment ratio, Carbon sequestration

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Introduction

Soil organic matter (SOM) is referred to as the 'life of soil' and has long been recognized as a reservoir of plant nutrients and a major factor in stabilization of soil structure. It influences a wide range of physical, chemical and biological properties of the soil and is considered the most important indicator of soil quality (Dalal and Mayer, 1986). Soil organic carbon (SOC) concentration reflects soil and ecosystem processes as well as past management of both agricultural and non-agricultural soils.

Cultivation has caused reduction in carbon contents of agricultural soils contributing to increase in atmospheric carbon concentration. This can be mitigated by suitable management practices that require an understanding of the SOC dynamics. Apart from soil type and climatic variables, the intensity of cultivation and the quantity of fertilizers and organic residues returned to the soil also affect SOC dynamics (Rasmussen and Collins, 1991).

Physical fractionation of soil yields organic carbon of different functions (Stemmer *et al.*, 1998). The distribution of SOM among size separates following different agronomic practices have qualitative bearing on SOM turnover which cannot be read directly from

changes in whole soil SOM content (Christensen, 1992). Carbon in particle size fractions gives an idea about the quality of the soil organic matter and also the turnover rates (Dalal and Mayer, 1986a). The carbon enrichment ratio reflected changes in fundamental soil properties related to SOM turnover, the decomposability of SOM in different size separates being different (Christensen, 1992). The objective of the present investigation was to study the C- distribution in the particle size fractions of a red soil at Zonal Agricultural Research Station (ZARS) GKVK, Bengaluru Karnataka that has been under rice cultivation for the last 25 years.

Resource and Research Methods

Soil samples were collected after harvest of rice from the field under long-term fertilizer experiment with rice fallow system at Zonal Agricultural Research Station, GKVK, Bengaluru from two depths (0-15 cm and 15-30 cm). They were air dried, ground with a clean wooden mallet and sieved to pass through 2mm sieve and stored in polythene bags for further chemical analysis. The treatments consisted of a T_1- control, T_2-100% N, T_3-100% NP, T_4-50% NPK, T_5-100% NPK and T_6-100% NPK+FYM. The treatments were replicated three times under Randomized Complete Block Design. Each plot, which is permanently laid out, measured $100m^2$.

Particle size fractionation of the depth wise soil samples was carried out by a modification of the procedure outlined by Stemmer *et al.* (1998). Soil pH in 1:2.5 soil: water suspension was determined using pH meter and soil carbon was estimated by using CHNS analyzer (LECCO). The soil was sandy loam of texture with initial pH of 4.52 and OC of 0.76 per cent. Initial available nitrogen, phosphorus (P_2O_5) and sulphur contents were 245 kg ha^{-1} and 42.2 kg ha^{-1} and 11.0 mg kg^{-1}, respectively.

Research Findings and Discussion

Particle size fractionation is based on the concept that SOM fractions associated with particles of different size (and also of different mineralogical composition) differ in structure and function and, therefore, play different roles in soil organic matter turnover. The distribution of SOM among size separates following different agronomic practices have qualitative bearing on SOM turnover, which cannot be read directly from changes in whole SOM content (Christensen, 1992).

Particle size fractionation allows the separation of SOM according to its origin and degree of transformation. Organic matter of recent plant origin is believed to be preferentially recovered in the sand size fraction, whereas more microbial processed material can be found in the silt and clay–size fractions (Cheshire and Mundie, 1981).

The sand was highest in contents in the soil and that was followed by clay and silt, respectively. Total carbon, total nitrogen, total phosphorus and total sulphur contents were highest in clay followed by silt and sand fractions in both the soil depths. Contribution of the of size fractions to total carbon, total N, total P and total S content of the soil was in the order: sand < silt < clay, even though the clay and silt content of the soil was low as compared to the sand fractions.

The differences among the treatments in respect of sand content of soil were not significant in both the depths. Sand content was marginally lower in second depth. The data on total C, N, P and S content in the sand are presented in Table 1(a). The differences among the treatments in respect of silt content of soil were not significant in both the depths. Silt content was marginally higher in second depth. The data on total C, N, P and S content in the silt are presented in Table 1(b). The differences among the treatments in respect of clay content of soil were not significant in both the depths. Clay content was marginally higher in second depth. The data on total C, N, P and S content in the clay fraction of soil are presented in Table 1(c).

Among the different size fractions, the clay had the highest content of all the four elements *i.e.* C, N, P and S followed by silt and sand fractions in both the depths of soil, irrespective of treatments. These results are in conformity with those of Buyanovsky *et al.* (1994); Amelung *et al.* (1999); Gerzabek *et al.* (2001); Geo Jose *et al.* (2007) and Sudhir *et al.* (1996). They also reported that the clay fraction contained about 43 per cent of the total SOC, 56 per cent of the total N, and 62 per cent of the total S.

The OC in the sand fraction contains mainly labile particulate materials having high turnover rates while OC in finer fractions of the soil are mineral associated and have very slow turnover rates (Stemmer *et al.*, 1998). The sand size SOM declines rapidly upon cultivation, mainly due to oxidation and the relatively stable forms enter silt or clay size fraction due to disintegration (Christensen, 1992 and Six *et al.*, 2002). A relative shift

of SOM from coarser to finer size separates due to cultivation has been reported by Tiessen and Stewart (1983). Bonde *et al.* (1992) also reported that cultivation caused a depletion of organic C in the sand and silt fractions and a relative enrichment in organic carbon of clay. Hence, the results of present study are in conformity with those of Tiessen and Stewert (1983) and Bonde *et al.* (1992). The soil of the experiment site has in fact been under intensive cultivation for a long period of time. The rate of loss of OC from clay fraction is generally lower than that of other fractions (Dalal and Mayer, 1986 b and c) resulting in an increasing proportion of total SOM remaining in clay fraction with cultivation. Their findings are similar with the results of present study since total C was also much higher in clay fraction as compared to other fractions. It is reported that clay provided

Table 1(a): Distribution of total carbon, total nitrogen, total phosphorus and total sulphur in sand fraction of soil as influenced by long-term fertilization

Treatments	Weight fraction (%)		Total C (mg kg^{-1})		Total N (mg kg^{-1})		Total P (mg kg^{-1})		Total S (mg kg^{-1})	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
T_1: Control	63.78	53.98	471	460	46.93	42.67	31.23	28.40	8.53	7.76
T_2: 100% N	63.79	53.99	465	460	56.63	51.48	27.75	25.22	8.86	8.05
T_3: 100% NP	63.73	53.93	470	450	57.12	51.93	53.00	48.18	10.46	9.51
T_4: 50% NPK	63.80	54.00	506	500	52.94	50.40	28.65	26.04	9.08	8.26
T_5: 100% NPK	63.78	53.98	517	500	58.74	53.40	54.56	49.60	10.68	9.71
T_6: 100% NPK + FYM	63.73	53.93	610	540	61.31	55.74	56.75	51.59	11.15	10.13
S.E.±	-	-	19.4	18.7	2.152	1.860	1.763	1.322	0.330	0.375
C.D. (P=0.05)	NS	NS	57.8	55.4	6.484	5.622	5.285	4.070	1.074	1.127

D_1: 0-15 cm; D_2: 15-30 cm NS=Non-significant

Table 1(b): Distribution of total carbon, total nitrogen, total phosphorus and total sulphur in silt fraction of soil as influenced by long-term fertilization

Treatments	Weight fraction (%)		Total C (mg kg^{-1})		Total N (mg kg^{-1})		Total P (mg kg^{-1})		Total S (mg kg^{-1})	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
T_1: Control	6.78	7.68	1570	1533	156.4	142.2	104.1	94.6	28.44	25.86
T_2: 100%N	6.79	7.69	1550	1533	178.8	171.6	92.45	84.1	29.52	26.84
T_3:100% NP	6.73	7.63	1567	1500	180.4	173.1	176.7	160.6	34.85	31.68
T_4:50%NPK	6.80	7.70	1687	1667	176.5	151.3	95.5	86.8	30.27	27.52
T_5: 100%NPK	6.78	7.68	1723	1667	195.8	178.0	181.8	165.3	35.60	32.36
T_6: 100%NPK+FYM	6.73	7.63	2033	1800	204.4	185.8	189.1	171.9	37.16	33.78
S.E.±	-	-	62.7	59.8	7.29	6.23	6.85	6.21	1.094	1.048
C.D. (P=0.05)	NS	NS	185.6	178.3	21.61	18.74	20.93	18.57	3.311	3.132

D_1: 0-15 cm; D_2: 15-30 cm NS=Non-significant

Table 1(c): Distribution of total carbon, total nitrogen, total phosphorus and total sulphur in clay fraction of soil as influenced by long-term fertilization

Treatments	Weight fraction (%)		Total C (mg kg^{-1})		Total N (mg kg^{-1})		Total P (mg kg^{-1})		Total S (mg kg^{-1})	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
T_1: Control	29.44	38.34	2669	2607	265.9	241.7	177.0	160.9	48.35	43.96
T_2: 100%N	29.42	38.32	2635	2607	320.9	291.7	157.2	142.9	50.18	45.62
T_3:100% NP	29.54	38.44	2663	2550	323.7	294.3	300.3	273.3	59.25	53.86
T_4:50%NPK	29.40	38.30	2867	2833	283.0	257.2	162.3	147.6	51.45	46.78
T_5: 100%NPK	29.44	38.34	2930	2833	332.9	302.6	309.5	281.0	60.52	55.02
T_6: 100%NPK+FYM	29.54	38.44	3457	3060	347.4	315.8	321.6	292.3	63.17	57.43
S.E.±	-	-	78.7	77.6	11.82	10.31	9.15	8.29	2.564	2.582
C.D. (P=0.05)	NS	NS	237.3	236.4	33.75	31.86	27.59	25.07	7.736	7.750

D_1: 0-15 cm; D_2: 15-30 cm NS=Non-significant

protection to SOM and made it relatively inaccessible through aggregation and micropore formation against microbial and enzyme attack. Buyanovsky *et al.* (1994) reported that the clay size particles contained organic carbon of high stability and slow turnover rates. Amelung *et al.* (1999) reported that both silt and clay fractions contained major amount of microbial derived organic material. Silt size particles are generally considered as medium term sink for added organic carbon and hence the OC concentration was less than that of clay fractions and higher than that of sand sized fractions Gerzabek *et al.* (2001) and Bangar *et al.* (2010)

Irrespective of the soil size fraction, the contents of OC, N and S were relatively higher in the plots treated with 100% NPK+FYM, followed by the plots treated with only NPK fertilizers in balanced dosage and very low in control plot and the plots treated with imbalanced dosage of nutrients. This trend is similar to the one recorded for soil OC, N, P and S. Since organic matter is a major source of N and also a good source of P and S in even in mineral soils, the trends in respects of N, P and S were similar to that that of carbon in the soil under all the treatments.

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